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Can ultrasonically disintegrated activated sludge be exploited as an internal carbon source for denitrification?

Nico Lambert, Ilse Smets, Jan Van Impe, Raf Dewil*

Chemical and Biochemical Process Technology and Control Section - Department of Chemical Engineering, KU Leuven, W. De Croylaan 46, B-3001 Heverlee, Belgium

** Corresponding author: nico.lambert@cit.kuleuven.be*

Introduction

In the performed research, the applicability as carbon source of an ultrasonic disintegration and a combined alkaline hydrolysis/ultrasonic treatment were investigated by an anoxic titrimetric biosensor based on the pH-STAT method. It should be noted that the organic carbon source is preferably rapidly degradable. In Activated Sludge Model 1 (ASM1) terminology, 3 types of dissolved COD may be present in the supernatant liquid of the wastewater, inert soluble COD (S_I), slowly biodegradable COD (X_S) and rapidly biodegradable COD (S_S). In order to ensure a rapid denitrification reaction, readily biodegradable COD (S_S) is preferred as electron donor.

This research makes an attempt to fractionate the released COD into its individual state COD variables. The readily and slowly biodegradable fraction of the released COD was investigated by both NUR and respirometric experiments in order to quantify the denitrification capacity, when ultrasonically disintegrated sludge is used as an internal carbon scource. Internal process variables like the active biomass concentration (X_{BH}) and readily and slowly biodegradable COD (S_S and X_S) are not directly measurable on the basis of on-line or lab scale analysis. Indirect methods by statistically reliable parameter estimation have been used to quantfy all the COD fractions.

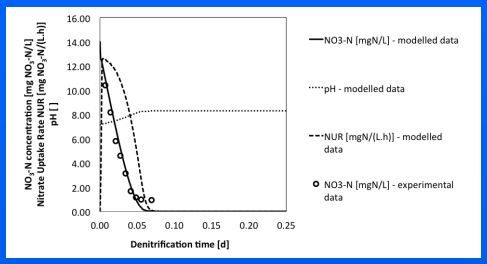

Figure 1: Example of results of a NUR experiment.

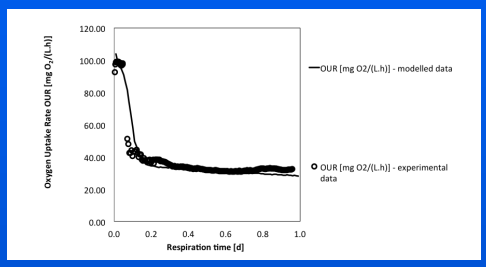

Figure 2: Example of results of a respirometric experiment.

Results & Discussion

1. Lysate characterisation by direct COD measurement

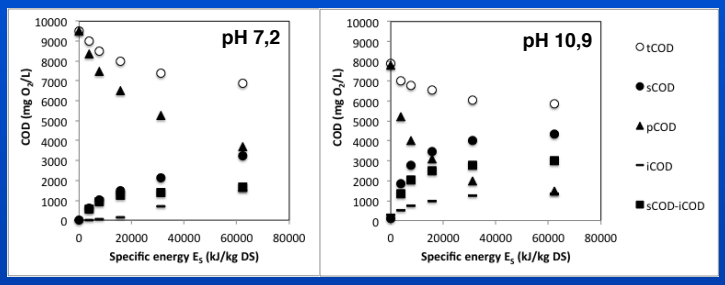

Figure 3: The course of the total COD (tCOD), soluble COD (sCOD), particulate COD (pCOD), inert sCOD (iCOD) and biodagradable sCOD (sCOD-iCOD) as a function of the specific energy (E_S) of the US treatment.

Activated sludge was exposed to a wide range of specific ultrasonic energies and the effect of an alkaline pre-treatment (pH 10,9) was examined:

- The alkaline pre-treatment results in a much higher sCOD release (approximately twice as much) for the same ultrasonic energy input.
- The increased sCOD release is caused by the hybrid effect of the alkaline hydrolysis and ultrasonic disintegration itself but is also the result of an extra loss of sCOD during the ultrasonic treatment without pH increase. Hereby more than 2600 mg COD/L is lost instead of 2050 mg COD in the case of the alkaline treatment.
- Efficiency factor for internal carbon source generation, expressed in mg released sCOD per mg reduced MLVSS = ΔsCOD/ΔMLVSS:
  - US treatment @ pH 7,2: 0,74 mg COD/mg MLVSS
  - US treatment @ pH 10,9: 1,15 mg COD/mg MLVSS

2. Lysate characterisation by respirometry

Experimental OUR data was used to estimate the rapidly and slowly biodegradable COD (S_S and X_S) with the aid of a Maximum Likelihood parameter Estimator (MLE). US treated sludge @ pH 7,2 and 10,9 were compared with each other. The inert COD (S_I) was experimentally determined at the end of each respiration experiment.

3. Lysate characterisation by anoxic NUR test

Experimental nitrate concentration data was used to estimate the rapidly biodegradable COD (S_S) with the aid of a Maximum Likelihood parameter Estimator (MLE). NaAc, US treated sludge @ pH 7,2 and 10,9 were compared with each other at a COD/NO_3-N ratio of 7.

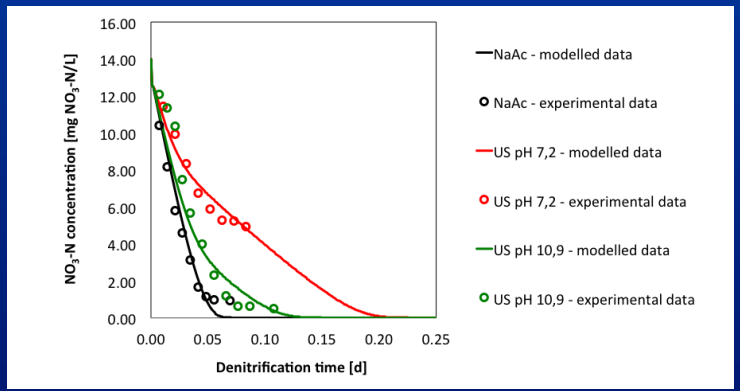

Figure 4: Fitting ASM1 to experimental nitrate data by the calculation of estimates for S_S.

Carbon source	NUR	OUR		
	S_S (mg O_2/L)	S_S (mg O_2/L)	S_I (mg O_2/L)	X_S (mg O_2/L)
• NaAc:	97,2	/	/	/
• US treated sludge @ pH 7,2 and 10.000 kJ/kg DS:	33,6	26,5	54,2	562
• US treated sludge @ pH 10,9 and 5.000 kJ/kg DS:	65,9	68,8	93,0	755

Conclusions

The alkaline hydrolyse step is an important prerequisite to guarantee successful denitrification at high reaction rates and this because a larger fraction of rapidly degradable sCOD (S_S) is produced when compared to single ultrasonic sludge disintegration. The alkaline hydrolysis at pH 11 ensures that the denitrification potential is almost equivalent to that of sodium acetate, allowing the internal carbon source to be considered as a worthy economic alternative for classic external carbon sources.